1   Description

2

3   Method for determination of a load characteristic which
4   indicates the load on electrical primary components

5

6   So-called automation systems are normally used nowadays in
7   order to control and monitor automated processes. The automated
8   processes may, for example, be technical processes, automated
9   production processes and distribution systems for electrical
10 power, for example electrical power supply lines or electrical
11 power supply networks. Automated processes such as these have
12 primary components, that is to say components which are
13 directly associated with the process; in the case of an
14 electrical power distribution system, such primary components
15 may, for example, be power supply lines, circuit breakers,
16 generators, converters and transformers.

17

18 An automation system for an automated process normally has
19 field appliances which are connected to the primary components
20 of the respective process, are arranged close to the process
21 and use suitable measurement converters, such as flowmeters and
22 concentration meters as well as current transformers and
23 voltage transformers, to obtain specific measurement data from
24 the process. The process can be monitored and controlled on the
25 basis of this measurement data. The measurement data may, for
26 example, be passed to suitable output appliances, for example
27 screen displays, and may be displayed there, for example in the
28 form of graphics or tables, to the operator of the respective
29 process.

30

1   In addition to the actual measurement data, field appliances
2   can also, for example, produce information about the respective
3   operating state of the primary components connected to them.
4   For example, in this context, German Laid-Open Specification
5   DE 100 50 147 A1 discloses a value which indicates the state of
6   machines being obtained by calculation of statistical
7   characteristics from measurement data recorded by the field
8   appliance, and part of which is processed further by computer.
9   Statistical characteristics such as these are, according to the
10   laid open specification, for example mean values, maximum and
11   minimum values, standard deviations and variances. Statistical
12   characteristics calculated for successive time periods are in
13   each case added to one another in order to characterize the
14   machine state; for example, a measure of the aging or wear of
15   the respective primary components is found on the basis of the
16   rate of change of these characteristics.
17
18   Furthermore, US Patent Specification US 6,490,506 B1 discloses
19   a method in which various measured values, for example the mass
20   flow of a liquid through the turbine, are recorded by means of
21   sensors on a turbine. These measured values are supplied to a
22   monitor in which, for example, the operating efficiency of the
23   turbine or its wear is determined.
24
25   The invention is based on the object of obtaining, as simply as
26   possible, details about the instantaneous load state of primary
27   components of an electrical power supply system.
28
29   According to the invention, this object is achieved by
30   proposing a method for determination of a
31

1 load characteristic, which indicates the load level on
2 electrical primary components and in an electrical power
3 distribution network, in which method the following steps are
4 carried out:
5 -   description values which describe an operating state of
6   the primary component are recorded by means of a sensor
7   which is connected to a field appliance which carries out
8   functions relating to the automation of the power
9   distribution network,
10 -   an overall sum of the description values is determined
11   over the duration of at least one predeterminable time
12   interval in order to form a load intermediate value, and
13 -   the load characteristic is produced as a function of the
14   magnitude of the load intermediate value in comparison to
15   a predeterminable load limit value.
16
17 The major advantage according to the invention is that
18 information about the instantaneous load state of the
19 respective primary component of a power distribution network
20 can be obtained by means of simple computation operations in
21 the form of addition of the description values over a
22 predetermined time period and of a value comparison, that is to
23 say, for example, a quotient formation from the load
24 intermediate value and the load limit value. Information such
25 as this makes it possible, for example, to distribute the power
26 flow more uniformly in a power supply network, and thus to
27 operate the overall network more effectively and
28 cost-effectively. In this context, in particular measured
29 values of a primary measurement variable, or else, for example,
30 numerical values for counting, for example switching operations
31 of a switch, should be regarded as description values.
32 Description values may be in analog or digital form.
33
34 As an advantageous development of the method according to the
35 invention, it is possible to provide for the load
36 characteristic to be

1   emitted from the field appliance or from the field appliance or
2   from a data processing device which is connected to the field
3   appliance. This makes it possible to emit the load
4   characteristic without major additional effort, for example for
5   specific output systems, from the field appliance itself or
6   from a data processing device which is nowadays normally
7   connected to it. The output may, for example, be in visual or
8   audible form.
9
10 Furthermore, according to a further advantageous embodiment of
11 the method according to the invention, it is possible to
12 provide for a load signal to be produced and emitted from the
13 field appliance or from a data processing device which is
14 connected to the field appliance as a function of the magnitude
15 of the load characteristic, when the load characteristic
16 indicates a particularly low and/or a particularly high load on
17 the primary component. This makes it possible, for example, for
18 a warning message to be produced in the form of the load signal
19 for the operator of an automation system when the corresponding
20 component is only lightly loaded or is loaded to its load
21 limit. Within the scope of the invention, it is, of course also
22 possible to produce a plurality of load signals, for example in
23 a different form or for different receivers.
24
25 According to one advantageous development of the method
26 according to the invention, a sensor which is already provided
27 in an automation system is also used to record the description
28 values. This means that no additional sensor, such as a
29 measurement converter, need be connected to the field appliance
30 for detection of the load characteristic, so that there is no
31 need for any complexity or any costs for additional components.
32 Conventional functions of the field appliance
33

1 which are already provided may, for example, be protective and
2 monitoring functions, or recording functions.
3
4 According to one advantageous refinement of the method
5 according to the invention, measured values of a primary
6 variable are used as description values. In this case, a
7 current flowing through the primary component can
8 advantageously be used as the primary measurement variable.
9 Current measured values represent conventional, frequently used
10 measurement variables in electrical power supply systems.
11
12 It is likewise also advantageously feasible to use a voltage
13 that is applied to the primary component as the primary
14 measurement variable. Voltage measured variables likewise
15 represent conventional, frequently used measurement variables
16 in electrical power supply systems. Furthermore, a temperature
17 of the primary component can also advantageously be used as the
18 primary measurement variable. The load of specific primary
19 components, such as electrical supply lines or transformers,
20 can also be indicated comparatively easily with the aid of
21 temperature measured values.
22
23 A further advantageous embodiment of the method according to
24 the invention is for the load characteristic to be produced
25 repeatedly, and for successive load intermediate values to be
26 added in a sum memory, forming an aging characteristic. This
27 allows an aging characteristic which indicates aging of the
28 respective primary component to be formed in a particularly
29 simple manner by adding successively determined load
30 characteristics. By way of example, an aging characteristic
31 such as this can be used

1   in order to determine an optimum servicing time for the primary

2   component.

3

4   In this case, it is also regarded as advantageous for the aging

5   characteristic to be emitted from the field appliance or from a

6   data processing device which is connected to the field

7   appliance. This makes it possible to emit the aging

8   characteristic in an advantageous form, without any further

9   complexity. This characteristic may be emitted visually or

10   audibly, analogously to the load characteristic.

1   Furthermore, it is regarded as being advantageous in this case
2   if an aging signal is produced as a function of the magnitude
3   of the aging characteristic in comparison to a predetermined
4   aging limit value for the field appliance or a data processing
5   device which is connected to the field appliance, and the aging
6   signal is emitted from the field appliance or the data
7   processing device. An appropriate signal can be produced in
8   this way, for example, when the corresponding primary component
9   needs to be serviced in the near future. To a very large
10   extent, this avoids unnecessary servicing work or checks of the
11   primary component. A plurality of aging signals can be
12   produced, analogously to the production of a plurality of load
13   signals.
14
15   Furthermore, in this context, it is regarded as advantageous
16   for the sum memory to be set to the value zero on starting up
17   the primary component. This is particularly appropriate in the
18   case of primary components which are being used for the first
19   time.
20
21   As an alternative to this, in the case of primary components
22   which have already been used in the past or have been stored
23   for a relatively long time period, it may be advantageous for
24   the sum memory to be set to a start value, which takes account
25   of previous use of the primary component, on starting up the
26   primary component.
27
28   One advantageous development of the method according to the
29   invention also provides that if the primary component is a
30   circuit breaker, the description values are in each case
31   determined only while the switching contacts of the circuit
32   breaker are open. In the case of a circuit breaker, this allows
33   load characteristics and any
34

1 aging characteristic which may possibly be produced to be
2 produced exclusively on the basis of the time period during
3 which the switching contacts of a circuit breaker are open,
4 during which time period the circuit breaker is particularly
5 heavily loaded, as a result of arc formation.
6
7 Furthermore, it may be advantageous if the primary component is
8 a circuit breaker, the number of switching processes carried
9 out by the circuit breaker is also determined by the field
10 appliance, an aging switching value is determined from this
11 number of switching processes, and the aging switching value or
12 a warning message derived from it is emitted from the field
13 appliance or from a data processing device which is connected
14 to the field appliance. This also allows the aging of a circuit
15 breaker to be indicated on the basis of switching processes
16 which have already been carried out.
17
18 In order to explain the invention further:
19
20 Figure 1   shows a block diagram of one exemplary embodiment of
21   a field appliance, which is connected to a power
22   transmission network, for production of a load
23   characteristic,
24
25 Figure 2   shows a block diagram of a further exemplary
26   embodiment of a field appliance, which is connected
27   to a power transmission network, for production of a
28   load characteristic and of an aging characteristic,
29
30 Figure 3   shows a method scheme for one exemplary embodiment of
31   a method for determination of a load characteristic,
32   and
33
34 Figure 4   shows a further exemplary embodiment of a field
35   appliance, which is connected to a power transmission
36   network, in the form of a block diagram.
37

1   Figure 1 shows a schematic block diagram of one exemplary
2   embodiment of a field appliance for production of a load
3   characteristic which indicates the load on a primary component
4   in an electrical power supply network. A line section 1 of a
5   power transmission network, which is not shown in any more
6   detail, or of a power transmission line has a primary component
7   2, which is indicated only schematically. By way of example,
8   this primary component may be a line part of the line section
9   1, a transformer, a circuit breaker, a generator or a
10 converter. The components that have been mentioned by way of
11 example are part of the power transmission network itself, as
12 primary components. The primary component 2 is connected to a
13 sensor 3, for example a measurement converter, which is
14 indicated only schematically in Figure 1 and is itself
15 connected on its output side to an input 4 of a field appliance
16 5. The field appliance 5 is, for example, part of an automation
17 system for automation of the power supply network. The input 4
18 of the field appliance 5 is connected to an addition module 7,
19 which is in turn connected by a control input to a timer 8. The
20 addition module 7 is also connected on the output side to a
21 first limit value module 9.
22
23 The method of operation of the arrangement illustrated in
24 Figure 1 will be described in the following text. Primary
25 description values M, for example primary measured values of a
26 primary measurement variable, that is to say of a measurement
27 variable which can be detected directly on the primary
28 component, which are suitable for description of the operating
29 state of the primary component 2, are recorded by means of the
30 sensor 3. In a situation such as this, by way of example, the
31 primary measurement variable may be the temperature of the
32

1 primary component, a voltage applied to it or a current flowing
2 through the primary component. Primary variables which are
3 based on a current and voltage may, for example, exist in the
4 form of instantaneous values, root mean square values, maximum
5 values or average values. Furthermore, it would also be
6 possible for the primary measurement variables to be in the
7 form of air humidity or, in the case of rotating machines such
8 as generators, a torque that is applied to a shaft, or its
9 speed of revolution. Other primary description values may, for
10 example, be numerical values which indicate the number of
11 switching operations of a switching component, as well as event
12 signals which, for example, indicate that a limit value has
13 been exceeded. Primary description values may be in analog or
14 digital form. The primary description values M are recorded by
15 the sensor 3 and are converted to measured values $\tilde{M}$ which are
16 proportional to the primary description values M. Furthermore,
17 if necessary, the primary description values M may also be
18 digitized in the course of this conversion by the sensor 3, so
19 that the description values $\tilde{M}$ can be transmitted in digital
20 form. The description values $\tilde{M}$ are then supplied to the input
21 4 of the field appliance 5, and are passed from there to the
22 input of the addition module 7, where the time profile of the
23 description values $\tilde{M}$ is added during a time interval which is
24 predetermined by the timer 8. As the result of the addition
25 process, the addition module 7 produces a load intermediate
26 value K* at its output, and this is supplied to the limit value
27 module 9, which compares the load intermediate value K* with a
28 predeterminable load limit value, and produces a load
29 characteristic K_1 as a function of the result of this
30 comparison. By way of example, a high load characteristic K_1
31 can be produced in this way when the ratio of the load
32 intermediate value K* to the load limit value is close to
33 unity; conversely, a low
34

1   load characteristic K_1 can be produced when this ratio is close
2   to 0.

3

4   The load characteristic K_1 may be emitted from the field
5   appliance by means of an output device, which is not
6   illustrated in any more detail in Figure 1. By way of example,
7   the output device may be a device for visual indication of the
8   load characteristic K_1, such as a display or a screen, or may
9   be a device for audible output of the load characteristic, such
10   as a signal horn or a loudspeaker.

11

12   A load characteristic K_1 produced in this way makes it simple
13   for the operator of the automation system for the power supply
14   network to optimize the load on specific primary components.
15   For example, the load characteristic K_1 can be used to identify
16   lightly loaded line sections of the power supply network and,
17   as a consequence of this to distribute more electrical power
18   onto such line sections. Analogously, very lightly loaded or
19   very heavily loaded transformers, generators and other primary
20   components of the power supply network can be identified, so
21   that it is possible in this way to distribute the overall load
22   more uniformly throughout the entire power supply network by
23   redistribution of electrical power – to the extent that this is
24   feasible. This allows a power supply network to be operated
25   more effectively overall, and thus also considerably more
26   cost-effectively.

27

28   Figure 2 shows a further exemplary embodiment of a field
29   appliance for production of a load characteristic and of an
30   aging characteristic determined from it. The major aspects of
31   the method of operation for production of the load
32   characteristic are the same as those already explained with
33   reference to Figure 1. The
34

1   corresponding components are thus identified by the same
2   reference symbols.
3
4   The additional functions of the field appliance 5 in comparison
5   to those in Figure 1 will be described in the following text.
6   As can be seen from Figure 2, the limit value module 9 also
7   produces one or more load signals W_1 as a function of the
8   magnitude of the load characteristic K_1 when the load
9   characteristic K_1 is very high or very low. A load signal W_1
10   such as this may either be emitted directly to the field
11   appliance 5, for example visually or audibly, or may be
12   supplied to an input of a data processing device 10 which, for
13   example, is arranged in a central control station, via a
14   communication line 12 which is suitable for this purpose. The
15   load signal W_1 can be processed further by means of the data
16   processing device 10, or it can be emitted in some suitable
17   form again. Furthermore, it is likewise possible for the load
18   characteristic K_1 to be emitted directly from the field
19   appliance 5 to the data processing device 10 which, after
20   comparison with a load limit value, either indicates the load
21   characteristic K_1 directly or emits a load signal W_1,
22   analogously to the operation of the limit value module 9. The
23   last-mentioned case would thus correspond to the signal
24   production being moved to the data processing device 10.
25
26   The load signal W_1 can be produced as a function of the
27   magnitude of the load characteristic K_1, for example, when the
28   primary component is only very lightly loaded. In the same way,
29   the load signal W_1 can be produced when the primary component
30   is very heavily loaded. It is also possible to provide a
31   combination of both conditions for the load signal W_1; it is
32   thus produced in this case when the load on the primary
33   component is light or heavy.
34

1   It is also possible for the load signal W_1 to be indicated, for

2   example, in the form of a type of traffic light, in which a red

3   indication indicates that a primary component is loaded close

4   to its load limit, an amber lamp indicates that the primary

5   component is loaded in an intermediate load range, and a green

6   lamp indicates that the primary component is very lightly

7   loaded. Quite clearly, an indication such as this may in each

8   case be modified, for example in terms of colors, in accordance

9   with the respective requirements.

10

11   A further function which is added in Figure 2 in comparison to

12   the field appliance 5 in Figure 1 comprises the production of a

13   so-called aging characteristic K_2 for the primary component 2.

14   For this purpose, the load intermediate values K* which are

15   generated by the addition module 7 during successive time

16   periods are supplied successively to a sum limit 13, in which

17   they are in turn added. This addition process results in a

18   respective aging characteristic K_2, which is emitted at one

19   output of the sum memory 13. This aging characteristic K_2 thus,

20   so to speak, indicates the accumulated load on the respective

21   primary component up to the current time, and can thus be used

22   to determine the aging of the primary component 2. For example,

23   this can be used to determine an optimum time for servicing,

24   repair or replacement of the primary component 2. The aging

25   characteristic K_2 may either be emitted directly from the field

26   appliance 5 (this is not illustrated in this form in Figure 2),

27   or may first of all be supplied to a further limit value module

28   14, which compares the aging characteristic K_2 with a

29   predetermined aging limit value. Depending on the magnitude of

30   the aging characteristic K_2 in comparison to this aging

31

1 limit value, an aging signal W_2 can in each case be produced
2 which, once again analogously to the load signal W_1, is emitted
3 either directly from the field appliance 5 or after
4 transmission to the data processing device 10 via a suitable
5 transmission line 15 from the data processing device 10. By way
6 of example, the aging signal W_2 may indicate whether the
7 primary component 2 needs to be serviced or, possibly, whether
8 the overall load-specific life of the primary component 2 will
9 be reached in the near future, and it must thus be replaced. A
10 visual indication of the aging signal W_2 may once again be
11 provided, for example, in the form of a traffic light
12 indication (for example green: little aging, amber: medium
13 aging, red: close to the age limit or "servicing required").
14
15 The further limit value module 14 may also be moved from the
16 field appliance 5 to the data processing device 10.
17
18 The sum memory 13 has an initial value range 16, in which a
19 start value can be entered for the addition of the load
20 intermediate values $K*$ in order to form the aging
21 characteristic K_2. In the case of a new (unused) primary
22 component, zero is normally entered in this case as the start
23 value, since the entire load-specific life of the component is
24 still in the future. If the primary component has already been
25 used once, or other aging of the primary component has taken
26 place, for example as a result of unfavorable environmental
27 influences, such as high air humidity or temperature during
28 storage of the primary component, the start value can also be
29 set to a value other than zero, in order to indicate that a
30 certain amount of aging of the primary component has already
31 taken place. This at the same time shortens the
32

1 load-specific life of the primary component that still remains
2 before its maximum aging limit is reached.
3
4 Figure 2 also illustrates a functional block 6 by means of
5 which the field appliance 5 can carry out further automation
6 functions for the power supply network or the primary component
7 2. For example, functions such as these may be protective
8 functions for monitoring of compliance with specific operating
9 parameters by the primary component 2; however, these functions
10 may also include a recording function for recording and storage
11 of time profiles of the description values $\tilde{M}$. As can be seen
12 from Figure 2, the same description values $\tilde{M}$ as those which
13 are also used to determine the load characteristic K_1 are
14 applied to the input side of the functional block 6. This
15 particularly advantageously allows a plurality of functions of
16 the field appliance to be carried out on the basis, for
17 example, of measured values of only a single measurement
18 variable, for example of a root mean square current value, so
19 that, when by way of example a field appliance which can
20 already carry out the functions contained in the functional
21 block 6 is upgraded by the addition of a further function for
22 the production of the load characteristic K_1 and of the aging
23 characteristic K_2 as well, no further components such as
24 additional sensors or measurement converters are required. The
25 load characteristic K_1 and the aging characteristic K_2 can thus
26 be produced in this way without any additional costs.
27
28 The components of the field appliance shown in Figures 1 and 2,
29 for example the addition module 7, the timer 8 and the limit
30 value modules 9 and 14, should in this context be regarded only
31 as functional modules and therefore need not be in the form of
32 components of the field appliance 5 in their own right. In
33 fact, nowadays, it is normal for functional modules such as
34 these to be in the form of control software for the field
35

1 Appliance 5. Individual modules of the control software would
2 then carry out the functions of the function modules that have
3 been mentioned.
4
5 Once again, a method for production of a load characteristic K_1
6 and of an aging characteristic K_2 are illustrated by way of
7 example in Figure 3, in the form of a schematic flowchart.
8
9 Primary description values M are detected in a detection step
10 21 and, after conversion and possibly digitization, are
11 transferred as description values $\tilde{M}$ to an addition step 22. A
12 load intermediate value K^* is produced in this addition step 22
13 by addition of the description values $\tilde{M}$ over a predetermined
14 time period. This intermediate value K^* is supplied to a
15 comparison step 23, where it is compared with a load limit
16 value, and a load characteristic K_1 is produced on the basis of
17 the magnitude of the load intermediate value K^* in comparison
18 to the load limit value. Furthermore, a load signal W_1 can
19 optionally be produced when the load characteristics K_1 are
20 very high or very low. The load characteristic K_1 and, if
21 appropriate the load signal W_1, is or are emitted in a suitable
22 form in an output step 24 which ends this branch of the method
23 illustrated in Figure 3.
24
25 In parallel with the emission of the load characteristic K_1 and
26 of the load signal W_1 in the output step 24, the use of the
27 method can also be ended at step 22, and the primary
28 description value recording can start again with the detection
29 step 21. This results in a sequence of successive load
30 characteristics K_1 and load signals W_1 being produced.
31

1 Optionally, however, step 2 can also be followed by a further
2 addition step 25 in which the respective load intermediate
3 values K* are now added up, thus forming an accumulated sum of
4 the load intermediate values K*. This results in a so-called
5 aging characteristic K_2 being produced, which indicates the
6 wear or the aging of the corresponding primary component. The
7 aging characteristic K_2 can optionally be supplied to a further
8 comparison step 26, in which the respective aging
9 characteristic K_2 is compared with an aging limit value, and an
10 aging signal W_2 is produced on the basis of the magnitude of
11 the aging characteristic K_2 in comparison to the aging limit
12 value, and is finally supplied to a further output step 27.
13
14 The limit value comparison in the step 26 may in fact also be
15 omitted, with the aging characteristic K_2 in this case being
16 emitted directly in the output step 27.
17
18 After the step 25, the method is started again with the
19 detection step 21, and a new run starts.
20
21 Finally, Figure 4 shows a further exemplary embodiment of a
22 field appliance for production of a load characteristic.
23 Figure 4 essentially matches Figure 2. Identical components are
24 also once again provided with the same reference symbols in
25 this case. The following analysis is based on the assumption
26 that the primary component 2 (see, for example, Figure 1) is an
27 electrical circuit breaker 2a.
28
29 A switching operation detection device 31 is additionally
30 connected to the electrical circuit breaker 2a in
31

1 Figure 4. The switching operation detection device 31 can, as
2 is shown in Figure 4, have the same primary description values
3 M of the primary component, that is to say of the circuit
4 breaker 2a, applied to it as the integration module 7; however,
5 it is also feasible for other primary description values to be
6 applied to the switching operation detection device 31.
7 Furthermore, the switching operation detection device 31 may
8 also contain a converter device, in order to produce
9 proportional description values, which correspond to the
10 primary description values. The switching operation detection
11 device 31 is used to identify switching processes of the
12 circuit breaker 2a, for example on the basis of characteristic
13 current profiles. Whenever a switching operation such as this
14 is detected, a switching signal S is emitted to the field
15 appliance 5.
16
17 In contrast to the arrangement illustrated in Figure 4, the
18 switching operation detection device 31 may, however, also be
19 included within the field appliance 5.
20
21 The switching signal S is transmitted to an assessment module
22 32, which counts the switching operations carried out by the
23 circuit breaker 2a and compares this total with the maximum
24 number of switching processes intended for the circuit breaker
25 2a. The assessment module 32 then emits an aging switching
26 value A, which can in turn be emitted directly at the field
27 appliance 5, or can be emitted after transmission via a
28 communication line 33 to the data processing device 10. The
29 aging switching value A can in this case directly indicate the
30 number of switching processes already carried out or else, for
31 example, the number of switching processes which can still be
32 carried out. Furthermore, an indication can also be displayed
33 analogously to the load characteristic K_1 and to the aging
34 characteristic K_2 in the form of a colored traffic light
35 indication,
36

1   in which case, for example, green indicates that a small number
2   of switching processes have already been carried out, amber
3   that a medium number of switching processes have already been
4   carried out, and red that the number of switching processes
5   carried out is close to the maximum possible number of
6   switching processes which may be carried out.
7
8   When the primary component is a circuit breaker 2a, in order to
9   determine the load characteristic K_1 on the basis, for example,
10 of the route mean square value of a current flowing through the
11 switching contacts of the circuit breaker, the current which
12 shall be considered is, in particular, that current which flows
13 in the form of an arc between the switching contacts during the
14 process of opening the circuit breaker, since the switching
15 contacts are subject to severe loads and wear during this time,
16 and this contributes to the aging of the circuit breaker. By
17 way of example, in a situation such as this, the field
18 appliance identifies an opening process of the circuit breaker
19 and records description values $\tilde{M}$ for determination of the load
20 characteristic K_1 only at this time. The aging characteristic
21 K_2 for a circuit breaker is likewise then determined only on
22 the basis of load intermediate values $K*$ determined during
23 opening of the switching contacts.
24